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Development of *Moringa Oleifera* LAM. seedlings in different substrates

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Abstract
Moringa oleifera Lam., known as moringa, is an arboreal plant belonging to the Moringaceae family, native to India, and has a high capacity to adapt to climatic conditions and arid soils. In this study we evaluated the initial development of seedlings of *M. oleifera* Lam. under different substrates conditions. The experiment was conducted in a completely randomized design, consisting of eight treatments resulting from combinations of the base substrate (85% soil, 3% carbonized rice straw and 12% coconut fiber). At 60 days after sowing, plant height, stem diameter, dry mass of the aerial part and root system, total dry mass were evaluated, in addition to the Dickson quality index (IQD). The best seedling growth occurred using the combination of 20% poultry litter and 10% bovine manure. Seedlings produced with substrates formulated with 20% poultry litter and 10% bovine manure showed gains in the evaluated variables, which could be a viable alternative for the production of moringa seedlings.
Keywords: cattle manure; forest seedlings; organic fertilization; poultry litter.

Desenvolvimento de mudas de *Moringa Oleifera* LAM. em diferentes substratos

Resumo
A *Moringa oleifera* Lam. conhecida popularmente como moringa, é uma planta arbórea pertencente à família Moringaceae, nativa da Índia que apresenta elevada capacidade de adaptação a condições climáticas e a solos áridos. Objetivou-se com este estudo, avaliar o desenvolvimento inicial de mudas de *M. oleifera* Lam a partir do uso de diferentes substratos. O experimento foi conduzido em delineamento inteiramente casualizado, composto por oito tratamentos, resultado das combinações do substrato base (85% de solo, 3% de palha de arroz carbonizada e 12% de fibra de coco). Aos 60 dias após a semeadura, avaliou-se altura da planta, diâmetro do colo, massa seca da parte aérea e do sistema radicular, massa seca total, além do índice de qualidade de Dickson (IQD). Foram encontradas as melhores variáveis, para crescimento das mudas, na combinação de 20% de cama de aviário e 10% de esterco bovino. As mudas produzidas com substratos formulados com cama de aviário 20% e esterco bovino 10% apresentaram ganhos nas variáveis avaliadas, podendo ser uma alternativa viável para a produção de mudas de moringa.
Palavras-chave: adubação orgânica; cama de aviário; esterco bovino; mudas florestais.

Introduction

Moringa oleifera Lam., popularly known as moringa, is an arboreal plant belonging to the Moringaceae family. The family is composed of only one genus (*Moringa*) and fourteen species and is popularly known by several common names such as “lírio branco”, “quiabo-de-quina”, “acácia-branca”, “árvore-rabanete-de-cavalo” and“cedro” (PEREIRA *et al*., 2014).

Native to India, it is currently found in several countries of the tropics and subtropics, as it has a high capacity to adapt to climatic conditions and arid soils (SANTANA *et al*., 2010; SANTOS *et al*., 2011). However, the plant has growth limitations in poorly drained soils (JESUS *et al*., 2013). In Brazil the largest crops of moringa occurs in the Northeast region, in the states of

Maranhão, Piauí and Ceará (OLIVEIRA JUNIOR *et al*., 2013).

Moringa has multiple uses, and can be used in human and animal nutrition, in the cosmetics and medicines industry and even as biodiesel (FERREIRA *et al*., 2008). Moringa seeds have also been used in the treatment of water for domestic use, due to the coagulant effect that helps in water purification (VIEIRA *et al*., 2008; SANTOS, 2010).

According to Lim (2012), the roots, bark, leaves, flowers, fruits and seeds act as cardiac and circulatory stimulants, having antitumor, anti-epileptic, anti-inflammatory, anti-spasmodic, diuretic, anti-hypertensive, anti-diabetic, hepato protective, antibacterial, and antifungal substances, reducing the cholesterol and showing antioxidant activities.

Although moringa grows in poorly fertile and sandy soils, attention must be paid to the substrate to prioritize efficiency in the production of seedlings (ALMEIDA *et al*., 2019). According to these authors, the success of seedling development depends on the knowledge of the substrate, since the production of quality and quantity seedlings is essential for the establishment of forest stands.

The substrates can be composed by a single component or by the mix of different components. However, the substrates must present adequate physical, chemical and biological characteristics, good aeration, moisture retention and root penetration facility, besides availability of acquisition, easy handling and transport (DELARMELINA *et al*., 2013; MARANHO *et al*., 2013).

The substrate composition can influence the development of the plant since it provides to the roots the necessary conditions for its growth and establishment, in addition, it is the main nutritional source for the seedling (SIMÕES *et al*., 2012).

Studying the type of substrate that is most suitable for the development of seedlings is important to establish the criteria to supporting the implantation of a seedling production system. Such studies can inform not only which type of substrate is more suitable, but also provide information aimed at reducing production costs. Therefore, this study aimed to evaluate the initial development of *Moringa oleifera* Lam seedlings grown under different types of substrates.

Material and methods

The experiment was performed in the forest nursery of the Federal University of the West of Pará Universidade Federal do Oeste do Pará (UFOPA) from august to october 2019. The area has an annual rainfall of 1,900 to 2,200 mm/year, Köppen Am climatic type, annual average temperatures of 25 to 27 °C and average altitude of 81 m (ALVARES *et al*., 2013). The average relative humidity of the air is 85% with a dry season, generally extending from July to November and a rainy season between December to June (INMET, 2020).

Moringa fruits were collected in November 2018 from a single tree from the urban area of Santarém, Pará. Subsequently, the seeds were removed manually and packed in paper bags, and stored in a cold chamber, with temperatures ranging between 13 and 14 °C, for 09 months. The viability and vigor of *M. oleifera* seeds are maintained for a period of up to 27 months when stored at temperatures ranging from 9 to 14 °C (SILVA *et al*., 2012).

For the production of seedlings, were used polyethylene bags with a capacity of 2 L, filled with homogenized substrates, sowing two seeds per container. After the emergency, thinning was carried out, leaving one seedling per container. The seedlings were irrigated manually once a day using a hose and a jet regulator.

The moringa seedlings were placed under 50% shade screen in a nursery, in a completely randomized design, consisting of eight treatments and thirteen repetitions. Each experimental unit consisted of thirteen polyethylene bags, totaling 104 plants.

To compose the base substrate, we used soil (85%), carbonized rice straw (3%) and coconut fiber in the proportions (12%) described in Table 1. For the treatments, we used three levels of poultry litter (0%, 10% and 20%) and three levels of bovine manure (0%, 10% and 20%). The poultry litter and cattle manure fermented by three months before installing the experiment.

Table1. Treatments and substrate composition (%) used for the production of seedlings of *M. olerifera* Lam.

Treatments	Inputs used in the substrate (%)				
	Poultry litter	**Bovinemanure**	**Black soil**	**Rice straw**	**Coconutfiber**
T1	0	0	85	3	12
T2	0	10	75	3	12
T3	0	20	65	3	12
T4	10	0	75	3	12
T5	10	10	65	3	12
T6	20	0	65	3	12
T7	20	10	55	3	12
T8	20	20	45	3	12

T1 = poultry litter 0%, bovinemanure 0%, black soil 85%, rice straw 3%, coconutfiber 12%; T2 = poultry litter 0%, bovinemanure 10%, black soil 75%, rice straw 3%, coconutfiber 12%; T3 = poultry litter 0%, bovinemanure 20%, black soil 65%, rice straw 3%, coconutfiber 12%; T4 = poultry litter 10%, bovinemanure 0%, black soil 75%, rice straw 3%, coconutfiber 12%; T5 = poultry litter 10%, bovinemanure 10%, black soil 65%, rice straw 3%, coconutfiber 12%; T6 = poultry litter 20%, bovinemanure 0%, black soil 65%, rice straw 3%, coconutfiber 12%; T7 = poultry litter 20%, bovinemanure 10%, black soil 55%, rice straw 3%, coconutfiber 12%; T8 = poultry litter 20%, bovinemanure 20%, black soil 45%, rice straw 3%, coconutfiber 12%;

The changes remained in the nurseries for 60 days. After this period, the samples were evaluated, by destructive method, to verify the influence of substrates on the following morphological variables: height of seedlings, stem diameter, fresh shoot weight, fresh root weight, dry shoot weight, dry weight root and total dry mass.

We calculated the Dickson Quality Index (DQI), which aims to indicate the quality of seedlings (DICKSON *et al*., 1960) by the variables: total dry mass, shoot height, stem diameter, dry masses of the shoot and the root, following the formula:

$$DQI = \frac{TDM}{\left(\frac{H(cm)}{SBD(mm)}\right) + \left(\frac{SDM(g)}{RDM(g)}\right)}$$

TDM = Total dry mass, H = Plant height, SBD = stem base diameter, SDM = shoot dry mass e RDM = root dry mass.

Height (H) was measured as the distance between the base of the stem and the apex of the youngest leaf, using a graduated ruler in centimeters (cm). The stem diameter (DC) was checked with a digital caliper and the values expressed in millimeters (mm). To determine the length of the seedling roots (CR), a ruler graduated in centimeters was used, measured from the apex of the root neck to the lower end of the main root.

The shoot dry mass (SDM), dry mass of the root (RDM) and total dry mass (TDM) were determined, after the separation of the plant (root and aerial part). The samples were weighed and placed in an oven at temperature 65 °C, until constant weight. TDM was determined using the sum of SDM and RDM.

We used an analysis of variance and comparison of means by the Tukey test at the level of 5% probability to test for the differences among treatments. All data were submitted to the Shapiro Wilk normality test, and the data that did not show normality were transformed, however, the data presented in the work are the original ones.

Results and discussion

We found significant statistical difference for the height of the moringa seedlings (Table 2) with an amplitude of 38.6 cm (T7 and T1). The highest average growth in this variable was observed for T4 (10% poultry litter) with 112.7 cm, and the lowest occurred on T1, with an average height of 74.1 cm. When compared to the other treatments, T4 differed from T1, T3, T6 and T8. There was no statistical differences among T2, T5 and T7.

Table 2. Result of the analysis of variance for *M. oleifera* Lam. seedlings produced on different substrates. H= height; SBD= Stem base diameter e RL= root length

TREATMENTS	H	SBD	RL
T1	74.1 b	4.5 d	17.8 a
T2	89.8 ab	5.4 cd	18.3 a
T3	77.6 b	5.8 bcd	20.1 a
T4	112.7 a	7.1ab	26.3 a
T5	89.6ab	6.8 abc	23.5 a
T6	82.7 b	6.0 abc	18.9 a
T7	105.3ab	7.9 a	29.9 a
T8	79.5 b	6.0abcd	19.2 a
CV%	24.1	20.2	43.9

*significant at 5%; ** at 1% of probability at Tukey test

T1 = poultry litter 0%, bovinemanure 0%, black soil 85%, rice straw 3%, coconutfiber 12%; T2 = poultry litter 0%, bovinemanure 10%, black soil 75%, rice straw 3%, coconutfiber 12%; T3 = poultry litter 0%, bovinemanure 20%, black soil 65%, rice straw 3%, coconutfiber 12%; T4 = poultry litter 10%, bovinemanure 0%, black soil 75%, rice straw 3%, coconutfiber 12%; T5 = poultry litter 10%, bovinemanure 10%, black soil 65%, rice straw 3%, coconutfiber 12%; T6 = poultry litter 20%, bovinemanure 0%, black soil 65%, rice straw 3%, coconutfiber 12%; T7 = poultry litter 20%, bovinemanure 10%, black soil 55%, rice straw 3%, coconutfiber 12%; T8 = poultry litter 20%, bovinemanure 20%, black soil 45%, rice straw 3%, coconutfiber 12%

The highest plant heights, found in T4, correspond to the development under treatment using the addition of only chicken litter. This substrate offers high amounts of nitrogen and other nutrients that favor the rapid growth in height of the plants, similar to the fertilization with urea (SOUZA, 2007; PEREIRA *et al*., 2013).

The treatments using 10% of bovine manure stood out concerning the others treatments using bovine manure in greater concentration (T2, T5 and T7), showing that this substrate was not efficient in greater proportions to influence growth in height.

The differences in height were influenced by the combination of organic substrates in the composition. Such results corroborate with Camargo (2011) and Medeiros *et al*. (2017) who also found organic fertilization as prone to the development of *M. oleifera* seedlings, mainly influencing growth in height and in dry matter. Organic fertilization provides a greater quantity and diversity of nutrients and an increase in the substrate micro-porosity, enhancing the water storage and its longer humidity time (OGBONNA *et al*., 2012).

Moringa seedlings ranged from 4.5 to 7.4 mm in average diameter growth. The highest average was obtained in the T7 treatment (20% chicken litter and 10% bovine manure), differing statistically from T1, T2 and T3. The T1, T2, T3 and T8 treatments showed the lowest growth average in the diameter of the stem (Table 2).

The treatments with addition of chicken litter and manure had the largest diameters, corroborating with Medeiros *et al*. (2017), who found better diameters with the addition of organic fertilizer in moringa seedlings grown in polyethylene bags in a nursery.

The best diameters were found in the fertilization percentages of 10% and 20% in the presence of the chicken litter compound, with a decline in the diameter when this percentage has only bovine manure or when it exceeds 40% of the composition with manure (T8). These results differ from Camargo (2011) who points out that the substrate must contain 45% of bovine manure as ideal for the production of moringa.

The root length averages ranged from 17.8 to 29.9 cm, with no significant differences between treatments (Table 2). Even so, the T7 showed root length 37.5% greater than the treatment with the lowest value (T1). Araújo *et al*. (2013) observed an improvement in the root growth of papaya seedlings when organic compounds from chicken bed and bovine manure were used in the composition of the substrates

Thus, the combination of both organic fertilizers present the best responses concerning the individual use of the substrates as in the work of Camargo (2011) and Medeiros *et al*. (2017),

who found mean root growth of 32.6 and 19.7 cm, respectively.

The T7 treatment provided the largest average increase (7.4 g) of shoot dry mass, but it was statistically equal to the other treatments. In contrast, treatments T1, T2, T8 and T3 were the ones that presented the lowest averages for this variable (Table 2). These results corroborate those found by Trazzi *et al*. (2013), when observing that the greatest gain in dry mass of the aerial part occurred in the treatments consisting of poultry litter, as well as for height and diameter.

Treatment T7 also show the highest TDM, but did not differ statistically from T6, T5, T4 and T3 but exceeded the values obtained in T1, T2 and T8 (Table 3). For this parameter, we can observe that the poultry litter combined with cattle manure in a lower percentage proved to be efficient for accumulation of biomass in the seedlings.

Table 3. Averages of shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM) and seedling quality index (DQI), at 60 days under different types of substrate.

Treatments	SDM (g)	RDM (g)	TDM	QDI
T1	0.61 c	0.1 b	0.8 c	0.04 c
T2	2.4 bc	0.1 b	2.5 bc	0.06 bc
T3	2.6 bc	0.41 ab	3.0 abc	0.15 abc
T4	4.7 ab	0.7 ab	5.3 ab	0.23 ab
T5	3.9 abc	0.59 ab	4.4 ab	0.22 ab
T6	3.6 abc	0.8 a	4.4 ab	0.24 ab
T7	7.4 a	0.7 ab	8.1 a	0.34 a
T8	2.4 bc	0.3 ab	2.7 bc	0.13 abc

Same letter in the column means no statistical difference according to the Tukey test at 5% significance
T1 = poultry litter 0%, bovinemanure 0%, black soil 85%, rice straw 3%, coconutfiber 12%; T2 = poultry litter 0%, bovinemanure 10%, black soil 75%, rice straw 3%, coconutfiber 12%; T3 = poultry litter 0%, bovinemanure 20%, black soil 65%, rice straw 3%, coconutfiber 12%; T4 = poultry litter 10%, bovinemanure 0%, black soil 75%, rice straw 3%, coconutfiber 12%; T5 = poultry litter 10%, bovinemanure 10%, black soil 65%, rice straw 3%, coconutfiber 12%; T6 = poultry litter 20%, bovinemanure 0%, black soil 65%, rice straw 3%, coconutfiber 12%; T7 = poultry litter 20%, bovinemanure 10%, black soil 55%, rice straw 3%, coconutfiber 12%; T8 = poultry litter 20%, bovinemanure 20%, black soil 45%, rice straw 3%, coconutfiber 12%

Moringa produces a large amount of dry matter when compared to other species. Oliveira *et al*. (2008) obtained total dry mass for *Schinus terebinthifolius* Raddi (aroeirinha) of 3.01 g, for *Acacia holosericea*. A. Cunn. ex G. Don (acacia) of 3.22 g, for *Cedrela fissilis* Vell (pink cedar) of 2.97 g for *Eucalyptus grandis* w. hill ex maiden (eucalyptus) of 2.94 g, levels that are low when compared to those obtained by the best treatments in the present study.

We found statistical difference in dry root mass between treatments. The lowest values were obtained in treatment T2 and T1, respectively. The highest values found were between T4, T6 and T7, with the highest average obtained in treatment T6 (Table 3). Pereira *et al*. (2010), state in their studies that chicken litter associated with soil has a significant effect on the development of seedlings of *Tamarindus indica* L. at an early stage.

The Dickson quality index has an intrinsic relationship with the variables related to the aerial part and the root system of the seedlings (DICKSON *et al*., 1960). Therefore, influenced by the higher values attributed to T7 and T6, which resulted in the highest values of seedling quality index (DQI) for these two treatments, with the index for T7 being superior, 88% when compared to the control.

Medeiros *et al*. (2017) found lower DQI values when evaluating moringa seedlings in the 1: 1 proportion of fertilization with black soil with bovine manure, with a 50% difference between this treatment and the control. The divergence between the data of this author and the present work, highlights the effect of the combination of chicken bed and cattle manure on the efficiency of the production of higher quality seedlings. Rodrigues *et al*. (2016) and Almeida *et al*. (2019) defend organic fertilization as an important factor in improving the quality of seedlings of several species because they present in their composition significant amounts of nutrients for their development.

The best results obtained for seedling growth were related to the combination of poultry litter (20%) and bovine manure (10%) in the composition of the substrate in the T7 treatment.

Conclusion

The seedlings produced using 20% of chicken manure and 20% of bovine manure in the composition of the substrate showed gains in the evaluated variables, consisting of a viable alternative for the production of moringa seedlings.

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